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CONTENTS

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RESULTS VS. IDEALS IN TECHNICAL EDUCATION[1]

RESULTS *vs.* ideals; performance *vs.* promises; accomplishments *vs.* good resolutions; graduating classes *vs.* college catalogues and prospectuses—such is life!

This is a commemorative occasion; a twenty-fifth graduation; a proper time to look backward and revise educational estimates.

Chauncey Rose, the revered founder of Rose Polytechnic Institute, had very definite ideals. His thought was of an education blending the industrial sciences with advanced academic and even collegiate instruction; the product to be, not scholars only, but men fitted for various mechanical, professional and industrial pursuits; and equipped with both intelligence and skill.

The first president of Rose Polytechnic, the lamented Dr. Charles O. Thompson, came here with very practical ideals, worked out during fifteen years at what is now the Worcester Polytechnic Institute. He transplanted to Terre Haute the system by which adequate scholarship is joined to skill gained by manual training in shops and laboratories. The Russian system in Moscow was contemporaneous; but there all manual operations of shopwork were for instruction only; material was consumed, but for the products there was no use or commercial value. Professor Calvin M. Woodward, in St. Louis, had also worked ten years on the manual training system, in which he aimed to

[1] A memorial address on the occasion of the twenty-fifth graduation at Rose Polytechnic Institute.

teach tool-theory and mechanical analysis apart from ordinary shop-practise—to conduct a secondary school with a liberal course of study in mathematics, science and language. But the Worcester system developed by Thompson and Higgins gave shop training under commercial conditions; the saleable products had a widely recognized use and value.

In his inaugural address, President Thompson clearly set forth the purpose and scope of an institute of technology. He defined the term technology as the application of the sciences to industrial ends. He then deprecated the confusion of ideas which would apply the term, technical education, to *any* course of teaching which aims at a directly practical result, as opposed to the old academic idea of the "college education." But when, as he said, a title is sought for those who engage in the higher occupations or professions, the word technologist is found to be too vague and awkward; hence such men are termed engineers, and the business, engineering.

We may note here that the term "engineering" may seem to lack breadth of meaning, suggesting chiefly mechanical devices, engines, machine shops, etc. But reference to the dictionary will set us right; for the first definition (now obsolete) of engine is "natural capacity," "ability," "skill"; and the derivation is from the Latin *ingenium* which is a composite of *in* and the root of *gignere,* to produce. Hence the original sense is very comprehensive, and the word, as used, quite appropriate. Indeed, the late Geo. S. Morison, civil engineer, held that every engineering work is a tool for accomplishing some specific purpose; that engine is but another name for tool; that the business of an engineer relates to tools; that a civil engineer must be capable of designing as well as handling tools; that the highest development of tools is an engine which manufactures power; that we are in the early stages of a new epoch, that of the manufacture of power; that civil engineering in its true meaning embraces every special branch; that the true civil engineer must be able to design as well as direct; and that, whether he be a railroad builder, a skilful surveyor, a mechanical engineer, or devoted to any other specialty, he must be more than a skilful workman, he must be an originator, a creator.

In President Thompson's statement of the high purpose of Rose Polytechnic, he recognized this principle and emphasized it by announcing that the young men who propose to be civil engineers will spend part of their practise-time in the machine shop. This was then an unusual policy in the schools, but it accorded with the earliest precedents of the profession. The first great civil engineers of the modern world, Perronet in France and his contemporary, Smeaton in England, one hundred and fifty years ago, developed marked inventive power and skill along mechanical lines. They devised and adapted their rude auxiliary machines for constructive purposes. Instead of steam hoisting engines, they had only man power and horse power. Smeaton constructed and operated pumps, water wheels, blowing engines and windmills, and invented astronomical and meteorological instruments.

You may remember the familiar anecdote of Rennie who, when traveling, lost caste among his fellow passengers by mending the broken axle of a disabled stagecoach—but one offended companion was astonished to find him at the breakfast table of a nobleman next day.

To justify his ideals at that time, President Thompson reported, as the results of fifteen years' trial of the system, that more than 95 per cent. of the graduates at Wor-

cester were in occupations for which their training had specifically prepared them. The subsequent twenty-five years at Rose Polytechnic show that eighty-six per cent. have been and are devoted to pursuits relevant to the training received here—including electrical engineering and architecture, which have been added during the period.

But a world-wide view of the ever-expanding field of technical education shows some complexity; there is discordance of results and ideals; criticism is abroad. The president of a leading American university,[2] where science is the leading interest, has recently recognized a prevalent doubt whether scientific studies have the same educational value as the classical curriculum; whether they confer the same depth and breadth of intellectual power; whether the outlook they give is as wide, or the life as large, as that founded on the old college training. Cecil Rhodes, an Oxford man, a phenomenal man of affairs, and would-be empire builder, gave his answer by founding the Rhodes Scholarships. However, to say the least, such criticism is quite premature. The ancient order of education was a growth of centuries; the new is scarcely half a century old. The immense body of knowledge, with its useful applications developed by scientific inquiry during the past two centuries, has but little relation to the ancient learning based on literature, rhetoric and art. The old system produced and still produces too much ineffective culture.

It is almost beyond belief that two distinguished professors in great universities have openly declared that increase in the utility of studies makes them of less value in educating men; and that "The practical aim of a *general* education is such training as shall enable a man to devote his faculties to matters which of themselves do not interest him." One of our honored leaders has termed this "superb foolishness." The modern scientific training aims at efficiency. If there are defects, the remedy is not in going back to the old, but in making one reinforce the other; and in finding a right adjustment of all the complex terms involved.

[2] President Remsen, of Johns Hopkins.

Perhaps it was a sense of the growing complexity of the situation, and a need of some agency of adjustment, that led to the formation of the Society for the Promotion of Engineering Education in 1893. This is the first and, so far, the only society of its kind in the world—a national congress of the teachers of engineering. The choice of its title raised the old question, of education *versus* training. Warning was urged against the danger of putting too much emphasis upon mere training to the neglect of the broader education. Furthermore, was the purpose of the society more truly expressed by the word *technical* or by the adjective *engineering?* It was decided that engineering includes technical, in describing the professional endowment of the man; and that education includes training, as the whole includes the parts—without putting too much stress upon mere drill and manual dexterity. Dr. Calvin M. Woodward, of St. Louis, has well said that the watchword of engineering education is *service.* It is to be in itself essentially serviceable.

> The idea of service underlies every detail of it, and that service is objective, altruistic; and therein it differs from that older education whose supreme object is "culture." . . . We all know that there is more than one avenue to culture; in point of fact there are many avenues, and we purpose to claim for the accomplished engineer his right to full and equal membership in the increasing brotherhood of culture.

Indeed, the term profession, as a vocation, signifies the application of special

knowledge and skill for the use and benefit of others, and not for merely personal advantage. So that a so-called professional man whose sole aim is selfish gain is discredited. Hence the famous maxim of Smeaton reveals the true professional instinct of the engineer. He said: "The abilities of the individual are a debt which he owes to the common stock of public happiness."

Right here we may observe that the most practical product of culture for the engineer is literary ability. From the time of Smeaton's report on the Edystone lighthouse to the latest papers and articles in our technical publications, the writings of engineers lose nothing, but sometimes gain by comparison with other literature of like kind. Instead of creations of sentiment and fancy the engineer deals with plain facts and procedure; knows exactly what he wants to say; and is only concerned to express himself with brevity and effectiveness. His subject-matter almost naturally leads him to adopt the prime qualities of style. He may be classed with other scientists who, in the words of another, "have caught with remarkably close ear the accents of the English tongue."

Doubtless this ability must be cultivated; young graduates do not often have it, for they lack the first essential, that is, having something worth while to say. But they may, and ought to have the preliminary training derived from preparation of required reports on special topics, and the graduating thesis. And many older engineers might have more influence and better professional standing by judicious speech and writing. They hesitate to "speak out in meeting," when it is their duty to inform the community on questions of engineering in relation to public affairs. The late Mr. Eads was a forceful writer and speaker; otherwise he never would have persuaded Congress to authorize the construction of the Mississippi (South Pass) jetties against the opposition of those who advocated the ship canal.

Deficiency in this particular has prevented capable and worthy engineers from gaining proper recognition. So long as the majority of engineers are content to take the attitude and play the part merely of the "hired man," so long will capitalists, lawyers and politicians "run the business" and dictate terms to those who, by their special knowledge and skill, are entitled at least to equal voice in the council, and often to direction of affairs.

The society or congress referred to has appointed committees of investigation which have made extended inquiries and rendered reports; vital questions of general policy and methods have been discussed; and much attention given to details of courses and subjects of instruction. A very brief statement of some of their findings will make the present situation more apparent, and elucidate our theme.

1. *Entrance Requirements* were formulated by a committee which made the ideal too high. In mathematics, they included much of what is known as higher algebra, advanced trigonometry, and facility in use of logarithms; also a wide range of physics and chemistry and extensive work in modern languages. Here was manifest the influence of the extreme dictation of the colleges and universities to the secondary schools. The protest of the latter has become very loud, both in teachers' conventions and in current periodicals. Studies that belong in college, perhaps to the extent of half a year of time, are crowded back upon the high schools and academies, which can not properly do the work, both because of inadequate teaching force and immaturity of many of the scholars. A writer in a leading magazine for May has

charged the higher institutions with ruining the high schools by diverting their strength and chief endeavors from the many pupils who can not go to college to the few who can. He says the people, who build and maintain these schools at great expense, are being cheated out of their proper return by not getting the education best adapted to their needs. A few years ago, the speaker saw an examination paper for admission to our foremost university, requiring solution of a problem in organic chemistry, which the instructors at one academy said would be a hard nut for them, and would require considerable time and some laboratory work for a proper answer. Within two weeks a pertinent criticism, widely circulated, is to the effect that the money for public education should be more wisely spent; that a more consistent system should be built up from the primary grades to the high school; and that the school authorities should then say to the universities: "Adapt your requirements to our best boys and girls."

2. The question of specialization and too much diversity of degrees has received earnest attention. A committee reported that, in 1904, no less than 85 different kinds of engineering degrees were offered, 22 for post-graduate work and 63 for undergraduate. Among these were bachelor of arts in five branches, bachelor of engineering in four branches, plain bachelor in nine branches, bachelor of philosophy in five branches, bachelor of science in twenty-eight lines, including textile industry, sanitary and domestic science and naval architecture; railway, architectural, municipal and sanitary engineering; four doctors and four masters of different designations; seven masters of science in different lines of engineering, and nineteen others, including practical chemist, master of mechanic arts, irrigation engineer, marine engineer, chemical engineer, architect, civil engineer in architecture, architectural engineer, etc. Only twelve of the post-graduate degrees and only 47 of the undergraduate degrees were conferred—that is, about two thirds of all those offered. It would perhaps be unkind and inconsiderate to describe this as *absurd* variety; it certainly indicates hopeless diversity, not to say confusion of ideals. The writer has elsewhere urged that the titles master and doctor in engineering are superfluous, and that it is a mistake to depart from the simplicity and dignity of the titles: civil engineer, mechanical engineer, mining engineer, architect, chemist, or, if you please, consulting chemist, electrical engineer and, possibly, one or two more.

Thousands of graduates from engineering schools during fifty years have proved that men with thorough knowledge of the fundamentals find occupation in all branches of engineering, irrespective of the kind of *degree*. Yes, looking back a century, to the first forty years of the U. S. Military Academy, we find about fifty men (trained to be *military* engineers) becoming chief or resident engineers on the canals and railways built in that period. Among these was Major Whistler who built the railroad from St. Petersburg to Moscow, 400 miles, for the Russian government. Why then give men such distinctive and wordy labels, as though the school had cast them into molds, or already projected them with correct aim at definite targets?

3. On the question of *Graduation Requirements* the president of one of our older engineering schools protested strongly against the tendency to "the crowding of the curriculum"; another against too much attempt to anticipate for one who is yet a student, and whose future can not be dictated by overdoing between narrow limits. The committee on this vital topic

worked out a consensus of actual schedules which allowed 7,450 to 8,100 "hours" for 27 subjects, including language, mathematics, the physical sciences and seven differentiated lines of engineering. From this they prepared an essential curriculum, grouping preparatory studies and engineering subjects into four parallel columns, respectively, for civil, mechanical, mining and electrical engineers. This was for the usual four year course. But if requirements for admission are lowered to the extent of half a year, as just suggested, some four-year courses, as now arranged, must be curtailed at various points.

Hence many raise the point that four years is quite insufficient to fulfil a broad enough program of culture studies and the ideal requirements for graduation. Consequently a growing interest in the five-year or six-year curriculum. The experience of the speaker for more than thirty years has been with a two-year program of studies and practise exclusively in the line of civil engineering—but *preceded* at first by *four* years of preparatory work in college, which, during the last fifteen years, has been reduced to *three* years of collegiate work in language and science, including two years of graphics. The five-year course is about as long as the young man of average financial resources can undertake; and too long for many, who then resort to an intermediate year of actual practise, which always brings more than financial return to the student, in better appreciation of his studies. This question is still under discussion. Professor Perry, of London, has said recently, in correspondence: "May I suggest that you Americans are trying to do too much at college. You are trying to teach *everything* at an engineering college. It seems to me that a college ought to teach a man how to go on *educating himself* after he leaves college. . . . If this is the aim of a college, then a five or six year course is all too long." But the University of Michigan has recently announced a six-year course with three degrees in sequence: bachelor of science, bachelor of engineering and master of engineering.

And Harvard University, within a few weeks, has ceased to debate the question by separating her engineering school entirely from the collegiate or undergraduate courses and making it distinctly a graduate school. Harvard thus tardily recognizes engineering as a profession, on an equality with law, medicine and theology. The fact of such equality has long been evident enough. The practicians in the art of engineering have long levied tribute from widely diverse fields of scientific inquiry. They have profited from the labors of the mathematicians since the days of the Bernouillis and Descartes; only they have discarded mathematical abstractions and made mathematics available as a working tool. The engineers have directed the researches of chemists, metallurgists and biologists to useful ends in the operation of water-works, works of sanitation, railmaking, etc. They have made chemical and bacteriological laboratories a necessary adjunct in various works. A civil engineer vindicated the veracity of Herodotus (discredited by some scholars) by making actual survey of and identifying the margin of the (so-called mythical) lake Mœris, and revealing to the modern world the vast irrigation system of ancient Egypt; thus showing how the British administration of to-day has singular analogy to the policy of Prime Minister Joseph in the control of the irrigation by the government. A civil engineer of to-day rescued the manuscript of Frontinus from neglect by the scholars, and introduced that capable and painstaking water-commissioner of ancient Rome

to the acquaintance of his confrères, younger by nineteen centuries. This vocation, which thus derives both *interest* and *culture* with *utility* from so wide a range of science, archeology and classic literature, is this anything less than a profession?

Many other subjects have received the serious and constant attention of the society in the endeavor to establish practicable ideals; among them are: Instruction by non-resident lecturers and abuse of the method by lectures; disproportion between laboratory or shop-work and class-room instruction; mixing of preparatory subjects and those of the proper engineering program; waste of time by too much vacation; more work with the individual directly, rather than so much with the class as a whole; instruction in the biography and history of the profession; research laboratories and investigational work by engineering schools; engineering jurisprudence; relation of philosophy to engineering instruction; training for leadership; ought instructors to engage in professional work? and many other topics relating to details of class-work, text-books, methods, etc.

The mere mention of so many and such diverse questions of common interest shows the scope of our theme, but only in part. The relations of engineering schools to polytechnic *industrial* education are worthy of passing notice. The U. S. Commissioner of Education reported in 1907 more than 100 state universities, state colleges, institutions of technology, etc., having an attendance of 33,000 male students classified as studying technology, applied science and engineering. This includes some state colleges of agricultural and mechanic arts which might be termed semi-professional schools, as well as some of the technical institutes. Some are yet in their infancy; resources, clientele and other conditions are widely different. One has been inaugurated in an adjoining state within a month. These and the trade schools or secondary schools which distinctly give *training* for particular occupations are generally fulfilling their purpose, by opening the doors of opportunity to many who otherwise would have no hopeful outlook.

The late Professor J. B. Johnson called attention to the monotechnic schools of Germany which are supported by the state or by the municipalities, and have fine buildings and complete equipment of every appliance needed to prosecute each its appropriate industry; also to the hundreds of special schools, supported by trades and associations, which have abolished apprenticeship, and have thoroughly applied science to give exact training; with the result that the superiority of Germany in commerce, based on the growth of her great industries, has been achieved almost in a generation. The three years of study in the monotechnic schools follow two years in secondary scientific schools (*i. e.*, to include sophomore year in our grading), so that the five years produce scientifically trained *directors* of *industrial enterprises.* Again, the commercial colleges of France, Belgium and Germany are training men qualified by their special education to invade every quarter of the globe as commercial agents and builders of industries.

In the United States, the recent Nelson amendment to the Morrill Acts of 1862 and 1890 gives increased national aid for the extension and betterment of the work of the state colleges of agriculture and the mechanic arts. Several of the states are also giving increased aid, and the state of Illinois has taken the unprecedented action of appropriating $50,000 for the *graduate* department of its university. The latest

movement of a national scope was presented in the Davis Bill before the house committee on agriculture of the sixtieth congress. This proposed, among other things, to provide an appropriation for agricultural and industrial instruction in *secondary* schools. It is open to question whether the general government is not already overburdened by its generous annuities to the state colleges, and whether the action now proposed does not more properly belong to the states themselves; whether it is not too much national interference in state education. This brief survey of abundant and diverse opportunities for various education presents an apparently ideal situation; manual training and "domestic engineering" for immediate industrial use, through grades of the semi-professional to the highest type of technology. Yet many point to the results as entirely disappointing.

Only a few days ago was heard a scathing indictment of the state universities by a prominent manufacturer and large employer of labor in our great inter-ocean metropolis. He advised the states to go out of the "higher education business and send the boys back to their homes to help support the family, instead of being a heavy expense." He is reported as saying: "Instead of teaching young men to seek labor they cause them to despise it, and the students leave the schools with the feeling that they are too good to work, and smart enough to make their living by their wits."

This is an extreme view of a so-called "self-made" and self-educated man. Now your true self-made man is not to be described by the jibe of the cynic, as "one who quit work when half done and then began to brag of the job." Rather are they men of hard sense who have achieved wealth and influence in spite of deprivations; and they compel a respectful hearing. If we ask this hostile critic for specifications he might reply: The schools and colleges do not teach good manners; they do not enforce sufficient discipline; the moral suasion theory is so pushed that teachers are often deprived of the power of discipline; the worst scholars become insolent; that the school life, with its artificial conditions, is so far removed from the matter-of-fact world that scholars are not prepared to grapple with the problems of self-support; that many acquire bad habits and learn to be extravagant rather than thrifty; and that, considering the many who have gained wealth and influence without early advantages, the results from the lavish facilities of to-day are out of proportion to the cost.

Professor Johnson, in arguing for a higher and better industrial education, compared the German system with the great diversity of endeavor in American education as follows:

> The common schools give no special preparation for any kind of employment; the manual training schools likewise fit for nothing in particular; our engineering schools fit for very narrow lines of professional employment, and commonly educate men away from the industrial pursuits rather than towards them; and, as for our so-called commercial colleges, what do they teach beyond arithmetic, book-keeping, stenography and type-writing? Where then does the specific scientific training for the manufacturing and commercial industries come in? I submit that it does not come in at all; that our factories and business houses are largely managed by men of little or no scientific training, who have learned their crafts in the traditional way; who are, however, of an inventive turn of mind and who read the trade journals. They are a great credit to the system that has produced them, and many of them have become self-educated into an excellent state of efficiency; but as a class they are far from the ideal directors of such business, and very far indeed from the standard already achieved in Germany. Their success can in most cases be attributed to the extraordinary conditions offered by a

new and rapidly developing country rather than to any superior ability on their part.[3]

The president of another eastern university has been quoted as saying: "Men go to college now for association and sentiment. It is a four-years' playground." There may be some reference here to the obtrusive intercollegiate contests. On the *unpublished* college calendar the usual sequence is: football, basketball, dramatic performances, glee-club exhibitions, spring track-meets for athletics, "junior promenade" and various festivities, baseball, boat-racing and, lately, in the north, polo. This "traveling show business," in the name of institutions which stand for the highest learning and culture, has the concomitants of notorious betting and the expenditure of thousands of dollars in the traveling expenses of the loyal college "cheering squads." Thus the advantages of sports, allowable in moderation, are lost in wild extremes; thus these distractions from the legitimate work are constant throughout the year; thus some seem to regard this as their chief interest and make a business of play. We have the authentic reminiscence of a graduate of a leading New England university, who remarked at a class reunion: "We would have had a really glorious time here, if it hadn't been for those studies." This is no joke. In another college a professor found, on investigation, that the extraneous activities, such as society matters, college papers, and the various sports and recreations, most of them quite proper and even helpful in their place, might easily absorb all of the time, so as to entirely exclude the real work of the college.

However, we recognize a minority of students who hold aloof from this, in good degree, attend to their proper business, and save the scholarship of the institution. Blessed is the man who has no money for such dissipation; he is not as poor as he thinks he is. It is noteworthy, also, that students of technology are much less affected by this evil; possibly from the majority of technical institutes it is entirely absent; and the speaker may add that all who come under his jurisdiction have to renounce any connection with that sort of thing.

This looks like a strong case for the critics of higher education. But their view is so near sighted that they see only the flaws; their method would be that of the Turk; their cure the guillotine, their doctor the executioner. They overlook the fact that some of the most generous contributors to the cause of higher education have been and are of those who lacked its advantages and know its value. Moreover they fail to notice that this regrettable degeneration of college ideals is more especially among those who, if they have a definite aim, will say it is "general culture," or the uplift of what they term "college life." The representatives of technical education, on their own behalf, do not need to enter a plea of "not guilty," for they can show that schools of technology have saved and will save the situation, in large measure. Do they not supply definite aims and a vital interest in what they are doing? The practise in laboratory and shop brings both mental and manual capabilities into harmonious cooperation. When a man has been out all day or even half a day in field practise, and has his notes to put in shape and check, he has little inclination to go out to blow horns or make bonfires.

The president of Cornell University, only day before yesterday, practically took the same ground in replying to the adverse criticism.

[3] Proc. Soc. for Promotion of Eng. Education, Vol. VI., p. 27.

It is a platitude that the example of the technical schools has revolutionized the programs of the older colleges within a generation; and that their students are prompted to strenuous endeavor, such as is unusual among students in the general courses. Indeed, one college president has commonly said to young men about to enter the engineering courses that they are expected to do about a third more work than the other students.

Nevertheless, as we have already noticed, there is much questioning of results in and among the engineering schools, and doubtless room for improvement. Each institution has its peculiar situation and its own problem. The individuality, determined by past history, traditions, resources, equipment, specific aims, personnel of the instructors and acquired momentum, must persist. We can not entirely harmonize ideals or secure uniformity in results. But all schools and their teachers may share in certain practicable ideals and some possible results which we may term *characteristics* of the best technical education.

In this aspect of our subject we may premise a broader definition, to wit: *Technical education is a course of instruction* (*including suitable training*) *which will best prepare a man to adjust himself to his future opportunities in technical pursuits.* Usually the man can not choose as he would; only a few find ideal opportunities after graduation. Most men do not find themselves until they face the responsibilities of their vocation. Hence the unwisdom of trying to make choices (or elect) too closely within the jurisdiction of the school. There should be, above all, a readiness to face the *vicissitudes of choice* afterwards.

A *first* and indispensable *characteristic* is *thoroughness.* "Whatever is worth doing at all is worth doing well." If you say this is an admitted maxim of life in any business, we reply that it is *systematically* violated in the whole range of American education, from the bottom up. There is a woful lack of sanity in overdoing the schooling all along the line, and too little thoroughness anywhere.

We develop this characteristic by living up to certain principles of action. Among these we specify (*a*): *A man must check his work.* Here is a marked contrast to some literary training. It is not enough for the man to *suppose* results to be right, when he hands them in; he must *know* that they are right. In leveling, he must close on his benches within the allowed limit of error; in other surveys, he must close his circuits; in the shop, every piece of his work must pass the tests of the gauges. In the draughting room, every computation must be proved by himself or another, and every drawing verified by methods which he can apply for himself, so that he can confidently invite any scrutiny. Such training makes the man sure of himself, and develops the sense of personal responsibility. This is so elementary as almost to need no statement, yet right here has been much complaint from the practicians. They say that in the attempt to cover too much ground, the schools do not teach the men to do their work well; that the young graduate makes many mistakes; that he does not check his results; that he does not keep a neat note book, or have care enough to take sufficiently complete notes; that he is not sure of himself in use of instruments, and can not be trusted to go ahead without supervision. There is no excuse for this; such fundamental training is the business of the school; whatever else is done, this must not be left undone.

As a case in point, a young man, out of college for an intermediate year of prac-

tise, was ordered to run a line of levels. He declined to use the instrument given him, saying that he had tried to adjust it and found an inherent defect which would vitiate his work; and, as it was a line 125 miles long in a bad country, he could not be responsible for correct results. He was commended for his discretion, given a better instrument, completed the task, and before the end of the year was made assistant engineer with an office in a railroad center. You will say that this is only ordinary caution. True; but many fail at such a point. Others had heedlessly used that instrument without proving it, probably on the assumption that a level is a level, and must do the work in some way. Again, a young graduate on the reclamation service was marked for enforced vacation, when the contractors had failed and work was curtailed. But his chief said, "No, I want to keep him; somehow he always gets results and has them right!"

As tending to thoroughness also we may state as *principle* (*b*): "Do not have too many irons in the fire at once." For the average man in a professional course, about two subjects followed collaterally are enough to engage all of his interest and enthusiasm. This does not rule out one other for culture or relaxation, but that should be according to his own preference and at odd times. Any overburden tends to produce distraction and mental worry, which impair the average accomplishment. Dispersion of the stream in an alluvial channel makes shoal water, concentration makes deep water.

Working on this principle of concentration along two lines secures better *continuity* and more *sustained interest* in a given subject; also it makes more feasible the policy of *individual instruction,* by not restricting the sessions in class-room or laboratory to a set period of minutes or hours. The speaker has used for many years the half-day as a unit period, whether the assignments are for recitation, field-work or laboratory.

In this principle also is included the necessity of judiciously excluding all non-essentials. The body of engineering literature is now so overwhelming in its quantity and range that the most diligent student can only get a glimpse of it; but he can learn to use the indexes and make his own card catalogue, through required reports on assigned topics; also how to unlock the storehouse; how to make his knowledge and elementary skill effective in emergencies.

We have noticed how largely the engineering profession utilizes the results of a wide range of scientific investigation. This gives apparent complexity; hence the division into the several recognized branches. Yet it is no contradiction to assert that a *second characteristic* of engineering education is the domination of a comparatively few controlling principles and methods.

If the members of the graduating class will take a retrospect of their entire four-years' course they may be surprised to find how much it can be boiled down to a not very large residuum of fundamental principles and data. In the applications of mathematics the really important subjects of engineering employ chiefly the more simple rules, methods and formulæ of arithmetic, algebra, geometry (including the analytical), trigonometry and calculus. The more intricate formulæ and the higher theorems are not extensively used even in mechanics of materials, theory of framed structures and hydraulics. The interesting applications of the theory of the higher plane curves in mechanism and machine design are almost the poetry of mathematics. The entire science and method of the graphic statics is plain application of

such simple mechanics as the "polygon of forces" and theorems of moments; and these again are elementary propositions of geometry concerning parallelograms and laws of similar triangles.

Engineering instruction in all the leading institutions is usually differentiated into parallel courses only after the first, second or third half year, because they all stand on this common substructure of correct theory deduced from mathematical and physical laws. In the usual subjects or branches, such as concrete construction, bridges, buildings and arches, municipal engineering (including pavements and streets, sewerage and sanitation, water-supply, etc.), thermodynamics and heat-engines, electrical engineering, etc., each includes a body of special data and detail which may be studied by the student in some essential points, but can only be fully appreciated as applied when he becomes a practitioner. The speaker would urge that in the attempt to spread over so wide a range we may get too far away from our base; he would impress upon the student the ultimate unity and simplicity of the science and art of engineering in the large.

A hydraulic engineer of large practise in mill construction and power development says he is constantly reviewing his mechanics and other fundamental theory, so as to have always at instant command the principles which must be his guide to safe practise. Another, a successful inventor and mechanical engineer, says it has been his habit to read from one to two hours daily in physics, chemistry and electro-technics, that he may keep posted, and work correctly in his laboratory. His fine library indicates scholarship and culture.

Enough said. We leave it to the student to take some simple principles like the theorems of moments, the law of the parabola or the principle of hydrostatic pressure, and trace them in their various applications throughout the range of engineering practise. For example, the simple principle of hydrostatic pressure so beautifully applied in the operation of bear-trap dams and automatic lock-gates—as on the Chicago drainage canal. The chief of the U. S. Engineer Corps has invented about fifteen forms of such dams and gates, some of which have been adopted with great success. The practicians are ever urging us to stick to the main principles and not attempt too much detail.

Other characteristics of the broad technical education might be specified, but we must pass on to consider what, by reasonable expectation, should be the *characteristics of the student, the graduate, the product.*

If we ask the officials of the schools, they would doubtless be nearly unanimous in claiming a rather good article. (Some years ago the recent graduates of a college of mechanical engineering were recommended to the U. S. government as competent to step in at once and operate the engines of the war vessels.) If we ask the young men themselves how they rate themselves — ? Here General Horace Porter's advice to the cadets is apropos: Never under-rate yourself in action, nor over-rate yourself in a report.

"Men are born as ignorant as they ever were"; but, looking back forty years, we see vastly increased facilities for the earnest student of to-day: spacious and convenient buildings, well-equipped shops and laboratories and expansion of class-work and practise-courses. Also, in many institutions, the benefit of the advanced policy by which leading instructors are or have been practising engineers. Yet the conditions of the school must ever be artificial, at least in part, since they can not supply the acute sense of responsibility which goads a man on the works under an exacting chief.

What then are the practicable characteristics which we can specify for our graduate?

He may be a competent instrument man in all ordinary surveying operations, fitted to become a surveyor after due experience.

He may be a careful and accurate draftsman immediately available in the office, but not content to remain a mere draftsman many years.

If he is an exceptional man, with the right personal equation, he may be an acceptable inspector on works, but this usually requires some previous experience with men and affairs.

As a possible assistant to a city engineer he may have to act in either or all of these capacities during the first season.

He may be competent to take subordinate responsibilities as mechanical or electrical engineer or foreman.

In railroad work he must usually begin low down, but he is qualified to win rapid promotion.

Whether in these or other openings, if he is wise, he will consider himself only a beginner, an humble learner, ready to take lessons from foremen and laborers, on practical details. He will avoid manifesting self-conceit, and "*restrain* his little knowledge" until it is wanted; else he may get a snub from his chief which he will remember for a lifetime.

It is another platitude that many technical graduates find their way into other pursuits for which their studies have indirectly fitted them—such as contracting, executive positions, scientific agriculture, etc.; otherwise the number of institutions and graduates would be excessive. We may say, then, that *adaptation* often is and always should be a distinguishing characteristic of the competent graduate. At times when opportunities are not ready to hand, he ought to know how to "size up" the situation and go to work to make one. He may have to conduct a campaign, by interviewing, public speaking and writing, to educate possible clients or the public, as to the value or necessity of some public improvement or private enterprise. For the engineer always labors under the odium of one who spends other people's money. Happy is he if he is where such matters are decided upon their merits. Too often he will be opposed by political influence or private spite. He needs sound judgment, tact and determination to disarm opposition and push his work wisely.

Some months ago a graduate of eight years' standing wrote to the speaker that he was manager of water-works, etc., in a certain town in a state south of the Ohio; that he had made the surveys and estimates, organized the company, sold the stock, built a 25-million-gallon reservoir, with pumping station and electric lighting station as an adjunct, and had a $50,000 plant "running finely."

Our term "characteristic" indicates the most important quality of all—*character.* Some cynic has said that education is but a varnish or polish; "you silver scour a pewter dish, it will be pewter still." This half-truth is so far true that our human result must depend largely upon the antecedent conditions of inherited traits or disposition, and family training of the student. The constant action and reaction between student and instructors during four or five years has directed and controlled the professional growth. Given the right moral qualities in the man, there has been corresponding growth in character, producing integrity—wholeness. The nature and methods of engineering studies and practise promote this. In these threatening times of extravagance and corruption incorruptible honesty in purpose and action is urgently needed. If our graduate has courage to resist the tempter, even though he may lose present gain, he will

surely be in demand when men "find him out." If he has enough of the love of God he will have enough of the fear of God to put down the fear of man. Employers inquiring for graduates often say: "We don't care so much for great attainments or brilliant qualities; but we must have men whom we can absolutely trust."

In brief, the crowning characteristic is unqualified trustworthiness.

The level-headed graduate will not be misled by the familiar talk about "room at the top"; if he applies the theory of probabilities to himself he will correct that fallacy quickly. Few have their works known and seen of all men; most of us are "unpraised and unsung." But he will cherish the noble discontent which will ever spur him to high endeavor, and not permit him to cease from being a "growing man."

Rose Polytechnic Institute, through its able president and superior faculty, is working out the high ideals of its founder. It is showing its students that technical education is not the mere appropriation of a mass of information concerning theories, methods and results; but rather the selection of essential principles and data, and the coordination of these into a sequence of available knowledge. It reveals the accumulations of knowledge and teaches how and where to find what the man wants to know. Its practical instruction emphasizes and clinches correct theory, and makes not a present but a possible expert. It plants the germs, arouses the appetite, supplies the working principles, and teaches men to "think it out" for themselves; each graduate is a good deal of a scientist and something of an artisan, prepared to learn something about everything, and, if he lives long enough, to learn everything about something.

The greater results of the operations of nature's forces are accomplished by noiseless action, as with solar energy and many molecular transformations. James Watt, whose labors gave to the world all the potentialities of the steam engine, is said to have worked ever in quietness and contentment of spirit. *This higher institution*, this noble *instrumentality in the kingdom of God,* in the quietness of effectual working, has already sent forth an army of alumni. As another squad of well-drilled recruits goes forth to join the ranks (perhaps the spirit of the founder in some way observant) the "order of the day" displayed by alma mater is: Every man is expected to render full measure of duty and service, in doing the world's work in the fear of God.

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INTERNATIONAL EXCHANGE OF STUDENTS

An influential committee has been formed in Great Britain to promote international exchange of students between the universities of Great Britain, Canada and the United States. Lord Strathcona is president of the committee and among the vice-presidents are Lord Curzon, chancellor of the University of Oxford; Mr. Balfour, chancellor of the University of Edinburgh; the prime minister, the lord chancellor and other distinguished men, including a large representation of professors from the British universities. Committees have not been yet organized in the United States and Canada, but leading educators have promised their cooperation.

It is proposed to establish two students' traveling bureaus, one in New York and one in London; an American secretary (resident in New York) and a British secretary (resident in London), both of whom shall be college men appointed to afford every facility to any graduate or undergraduate of any university who wishes to visit the United States, Canada or the United Kingdom for the purpose of obtaining an insight into the student, national and industrial life of those countries.